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# QUAD FLAT NO-LEAD (QFN) GRID ARRAY PACKAGE, METHOD OF MAKING AND MEMORY MODULE AND COMPUTER SYSTEM INCLUDING SAME

## BACKGROUND OF THE INVENTION

### [0001] Field of the Invention:

The present invention relates generally to semiconductor packaging. More specifically, the present invention relates to semiconductor packaging using a quad-flat package design incorporating a lead frame and providing an increased number of input/output contacts arranged in a grid array.

### [0002] State of the Art:

Conventional quad flat packages (QFP) are formed with a semiconductor die connected to a lead frame and being encapsulated to form a package such that a plurality of leads extends laterally outwardly from each side of the periphery of the encapsulating structure. Such a configuration is relatively simple in design and may be efficiently produced. However, the QFP-type semiconductor has shown various design and production limitations. For example, reducing the overall package size of a QFP becomes difficult because of the arrangement of leads about the lateral periphery of the package. This is particularly evident when reduced package size is attempted to be combined with increasing the number of input/output (I/O) connections required for the smaller yet ever more complex dice representing the state of the art.

[0003] In order to either reduce the size of a conventional QFP while at least maintaining, if not increasing, the number of connections or to increase the number of I/O connections while at least maintaining, if not decreasing, the package size, a higher density of connections would be required along the package perimeter. However, such an increased density of leads about the package perimeter inherently requires a reduced pitch or spacing between adjacent leads and promotes an increased likelihood of cross-talk and signal interference as well as making such packages more difficult to fabricate.

[0004] In an effort to increase the number of connections in an integrated circuit (IC) package while maintaining or decreasing the overall size, alternative packaging arrangements have been implemented. For example, grid array devices such as pin grid arrays (PGA's), ball grid

arrays (BGA's), land grid arrays (LGA's) and their associated variants have been used to reduce package size while and increase input/output connections. As an example of a grid array type device, a BGA device employs a number of input/output connections in the form of conductive bumps, such as solder balls, extending transversely from a major surface of the package in a pattern, or "array," of columns and rows. The conductive bumps may be formed on one surface of a circuit board or other interposer substrate and are in electrical connection with bonding pads on the opposing surface of the circuit board. A semiconductor die is coupled to the bonding pads, such as by wire bonding, to establish electrical connections from the bond pads of the semiconductor die to the conductive bumps. The resulting assembly is then typically encapsulated such as by transfer molding with a filled polymer with the array of conductive bumps being left exposed for subsequent electrical connection to higher level packaging such as a carrier substrate. The conductive bumps are configured to be coupled to a mirror image pattern of terminal pads on the carrier substrate which may comprise a printed circuit board (PCB) or another structure by reflowing the solder. In essence, a BGA device increases the number of input/output connections by allowing the connections to be positioned over substantially the entirety of a major surface of the package rather than extending laterally outwardly from the periphery of the package such as in a QFP.

[0005] While BGA and other grid array devices provide an increased number of input/output connections and may allow a simultaneous reduction in size for a given package, such devices are not without their own limitations and drawbacks. For example, the use of circuit board interposers, upon which the array of conductive elements is formed, imposes limitations on the size of the package since the circuit board is typically larger than the semiconductor die. Additionally, the circuit boards used in making BGA packages have been known to take on moisture during the fabrication process leading to subsequent cracking and warpage which ultimately renders the device unusable. Furthermore, the cost of circuit boards used in the fabrication of grid array type devices may also may also be viewed as a drawback.

[0006] In view of the shortcomings in the art, it would be advantageous to provide a semiconductor die package which allowed for a higher density of input/output connections

without increasing package size. It would further be advantageous to provide such a package having a patterned array of input/output connections formed from a lead frame.

[0007] Additionally, it would be advantageous to provide a method of producing such a package, and the lead frame utilized such a package, which does not require significant changes in tooling or fabrication processes such that the method is easily and efficiently implemented without incurring significant capital costs for new equipment or an increase in process steps.

#### BRIEF SUMMARY OF THE INVENTION

[0008] One aspect of the invention includes a method of forming a semiconductor die or integrated circuit package. The method includes providing a semiconductor die having a plurality of bond pads located on an active surface thereof. A lead frame having a plurality of conductive leads is provided adjacent the semiconductor die. A first bond pad on the semiconductor die is electrically coupled to a first portion of at least one conductive lead and a second bond pad is coupled to a second portion of the same lead. The first portion and second portion of the lead are then electrically isolated from one another to form two individual conductive elements from the original conductive lead. Additionally, an insulative encapsulant may be formed about the semiconductor die and at least partially about the lead frame while allowing a portion of each individual conductive element to remain exposed for subsequent electrical coupling with an external electrical circuit such as a carrier substrate.

[0009] The individual conductive elements may, for example, be electrically isolated from one another by saw cutting the conductive lead subsequent to the first and second portion being coupled to the bond pads of the semiconductor die. Also, a severance region may be predefined in the lead between the first portion and second portion so as to help facilitate the electrical isolation of the two portions. The severance region may include a notch or recess formed by scoring, cutting or etching partially through the material of the lead. Encapsulant covering the semiconductor die may be extended into the notch or recess of the severance region prior to isolating the first portion and second portion to help retain the first portion and second portion in their respective positions once they have been separated from one another by complete removal of any intervening lead material.

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**[0010]** Another aspect of the present invention includes a method of forming an array of electrically conductive elements for an integrated circuit package. The method includes disposing a semiconductor die having a plurality of bond pads on an active surface thereof on a lead frame including a plurality of leads. At least two bond pads of the semiconductor die are electrically coupled with each lead of the lead frame. The leads are then severed between the locations of coupling to form at least two electrically isolated conductive elements, each such electrically isolated conductive element being coupled to an individual bond pad on the semiconductor die.

**[0011]** The present invention also includes a lead frame of a first design. The lead frame includes a plurality of individual leads. At least one of the plurality of leads includes a first bonding region, a second bonding region and a severance region located between the first and second bonding regions. The severance region is configured to facilitate separation of the first bonding region from the second bonding region subsequent to connection of bond pads of a semiconductor die to the respective first and second bonding regions and encapsulation of the lead frame and semiconductor die to form an integrated circuit package.

**[0012]** The present invention further includes a lead frame of a second design. This lead frame includes a die paddle configured for attachment of a semiconductor die thereto. The lead frame also includes a plurality of conductive elements each having at least two bonding regions. The bonding regions are arranged in a grid array pattern which includes a first peripheral row of bonding regions spaced about a periphery of the die paddle and at least one other peripheral row of bonding regions spaced laterally outwardly from the first peripheral row.

**[0013]** Yet another aspect of the invention includes a semiconductor die or integrated circuit package. The integrated circuit package includes a semiconductor die, a lead frame and an electrically insulative encapsulant. The lead frame includes a plurality of spaced conductive elements arranged in an array including a first set of conductive elements on a major surface of the package and adjacent a lateral periphery thereof and at least one other set of conductive elements inwardly adjacent the first set. The insulative encapsulant extends over the semiconductor die and at least partially over the lead frame while allowing a portion of each of the conductive elements to be exposed on the major surface for connection with an external electrical circuit. At least one

concavity or other recess is defined between and electrically isolates at least one conductive element of the first set and an adjacent conductive element of the at least one other set.

[0014] In accordance with another aspect of the invention another integrated circuit package is provided. The integrated circuit package includes a semiconductor die having a plurality of bond pads and a lead frame having a plurality of conductive leads. Each of the plurality of leads is electrically coupled to at least two bond pads of the plurality of bond pads.

[0015] In accordance with another aspect of the present invention a memory module is provided. The memory module includes a carrier substrate in the form of a module board configured to be electrically coupled to another, higher level packaging structure such as a motherboard, enabling the memory module to communicate with a processor. At least one integrated circuit package having features such as those described above is electrically coupled to the module board.

[0016] In accordance with another aspect of the invention, a computer system is provided. The computer system comprises an input device, an output device, a processor coupled to the input and output devices, and a memory module, such as described above, coupled with the processor.

#### BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0017] The foregoing and other advantages of the invention will become apparent upon reading the following detailed description and upon reference to the drawings in which:

[0018] FIG. 1 is a plan view of the bottom of an IC package according to one embodiment of the present invention;

[0019] FIG. 2 is a cross-sectional view of the IC package of FIG. 1;

[0020] FIGS. 3A and 3B are enlarged views of the section specified in FIG. 2 at various stages of manufacturing;

[0021] FIGS. 4A and 4B are plan views of an IC package according to alternative embodiments;

[0022] FIG. 5 is a plan view of a lead frame strip according to one embodiment of the present invention; and

[0023] FIG. 6 is schematic of a computer system incorporating the IC package of the present invention.

#### DETAILED DESCRIPTION OF THE INVENTION

[0024] FIGS. 1 and 2 depict one embodiment of an integrated circuit package of the present invention in the form of a quad flat no-lead (QFN) grid array package 10. FIG. 1 presents a view of a major surface comprising the underside of the QFN package 10, while FIG. 2 shows a cross section of the QFN package 10 taken along section line 2-2 as shown in FIG. 1. The QFN package 10 includes a semiconductor die 12 positioned on and secured by its back side to a die paddle 14, die paddle 14 originally comprising a portion of a lead frame as will be hereinafter described. Conductive elements 16 are positioned about the die paddle 14 in a grid array pattern, outwardly of semiconductor die 12 and adjacent the lateral periphery of QFN package 10. The die paddle 14 and conductive elements 16 may be formed of any suitable material such as copper, aluminum, alloy 42 or any other suitable conductive material for lead frames as understood by those of ordinary skill in the art.

[0025] The grid array pattern of the conductive elements 16 may be described in various geometrical terms such as a grid having a specified number columns and rows. However, due to the general placement of the conductive elements 16 outwardly of the semiconductor die 12 and generally adjacent the periphery of the QFN package 10, the grid array structure will be discussed in terms of peripheral rows. Thus, the QFN package 10 shown in FIG. 1 and 2 includes a first inner peripheral row 18A and a second outer peripheral row 18B of conductive elements 16.

[0026] The language "peripheral row" is used herein for convenience in describing the configuration of the QFN package 10 and should not be understood as requiring all of the conductive elements 16 to be located at or on the peripheral edge of the QFN package 10, nor should such phraseology be taken to mean the that a given peripheral row of conductive elements 16 must circumscribe the entire die paddle 14 and semiconductor die. While it is desirable to have the conductive elements 16 positioned about each side of the QFN package 10 so as to maximize the number of conductive elements 16 in the package, some designs may not require such an arrangement. Alternatively, some configurations may include peripheral rows that only partially

circumscribe the die paddle 14 and semiconductor die 12, such as arrangements where peripheral rows lie on opposing sides of the QFN package 10.

[0027] The conductive elements 16 are each conductively coupled to a bond pad 22 on the active surface of semiconductor die 12 such as by wire bonds 24. The semiconductor die 12 and wire bonds 24 are encapsulated with an electrically insulative (dielectric) material 26 which also partially encapsulates the conductive elements 16, extending between die paddle 14 and the inner peripheral row 18A of conductive elements 16, between the inner peripheral row 18A of conductive elements 16 and the outer peripheral row 18B of conductive elements 16 and between laterally adjacent conductive elements 16 of each of the peripheral rows 18A and 18B. The encapsulant material 26 may comprise a silicon particle-filled polymer encapsulant applied under heat and pressure by transfer molding, as well known in the art.

[0028] The conductive elements 16 each have an exposed surface 28 on the bottom major surface of the QFN package 10 for subsequent electrical coupling with another electrical component such as a carrier substrate (not shown). Such connection may be made, for example, through the use of conductive bumps 28b, shown in broken lines for clarity. Such bumps may include, for example, solder bumps which are stenciled onto conductive elements 16 and then reflowed to form balls, conductive or conductor-filled epoxy columns or pillars, or self-supporting spheres (either conductive or insulative) covered with a conductive material. It is further contemplated that an anisotropic, so-called "Z-axis" conductive material comprising laterally-spaced conductive elements in a dielectric film and oriented transversely to the plane thereof may also be employed to connect conductive elements 16 to a carrier substrate. All of the foregoing approaches, and others, are known to those of ordinary skill in the art and are not to be taken as limiting of the present invention.

[0029] The inner peripheral rows 18A and outer peripheral rows 18B of conductive elements 16 adjacent each edge of QFN package 10 are shown to be separated from one another by an elongated, trough-like concavity or recess 30. As shown in FIG. 2, the concavity or recess 30 is formed as an elongated saw cut or scribe line extending from a first lateral edge of the QFN package 10 to an opposing lateral edge. However, the concavity may be formed according to other techniques known in the art such as, for example, a masking and etching process. In the



embodiment shown in FIGS. 1 and 2, the concavity or recess 30 serves to create the individual conductive elements 16 of the two peripheral rows 18A and 18B from a single row of individual, laterally extending leads of a lead frame. The fabrication process can be seen more clearly with reference to FIGS 3A and 3B. FIG. 3A depicts a partial section of the QFN package 10 showing the QFN package 10 at a stage in fabrication prior to formation of the individual conductive elements 16. The QFN package shown in FIG. 3A includes a single lead 16' rather than individual conductive elements 16. It is further noted that there are multiple wire bonds 24 connected to different bonding regions 32, 34 of the lead 16'. A severance region 36, shown as an upward-facing notch, is preformed in the lead 16' and subsequently filled with encapsulant 26 subsequent to attachment of semiconductor die 12 to die paddle 14 and wire bonding of a bond pad 22 (not shown in FIG. 3A) to bonding regions 32, 34. The notch of severance region 36 may be formed by various processes such as saw cutting, scribing, scoring or etching of the lead 16' prior to encapsulation of the lead 16' and wire bond 24 and preferably prior to attachment of semiconductor die 12 to die paddle 14.

[0030] Subsequent to the application of encapsulant 26 the lead 16' may be severed, such as through the aforementioned saw cutting or etching, to form individual, electrically isolated conductive elements 16 as shown in FIG. 3B. Each conductive element 16 is connected to a wire bond 24 and thus to a bonding pad 22 of the semiconductor die 12. It is noted that the severance region 36 serves various purposes. First, the severance region 36 identifies an area of separation on the lead 16'. This helps to identify the individual bonding regions 32, 34 during wire bonding of the lead 16' to the bond pads 22 of the semiconductor die 12. Additionally, the severance region 36 allows for the formation of a more shallow concavity or recess 30 during the separation of the lead 16' into individual conductive elements 16, such as to minimize the potential for damage to QFN package 10. Also, by forming the upward-facing notch in the severance region 36 prior to encapsulation, the transfer-molded encapsulant 26 flows under pressure into the notch and substantially laterally about at least three sides of the ultimate location of each conductive element 16 to form a structural member 38 between and about the locations of individual conductive elements 16 to more effectively tie the conductive elements 16 to encapsulant 26,

precisely fixing their locations and enabling the package to withstand the stresses placed on leads 16' without damage thereto or movement thereof.

[0031] While the severance region 36 is desirably in the form of a notch or recess as shown, it is contemplated that the severance region 36 of the lead 16' may simply be a designated area of separation without a notch or other physical feature. It is noted that in such a case, the concavity or recess 30 extending upwardly from the bottom major surface of QFN package 10 would penetrate through the entire thickness of the lead 16' and there would be no encapsulant 26 formed between the adjacent inner and outer individual conductive elements 16 to serve as a structural member 38. If desired, a structural member 38 could be formed after the formation of the concavity 30 by filling same with dielectric material regardless of whether or not an upwardly-facing, preformed notch or recess in each lead 16' is used to facilitate the formation of individual conductive elements 16.

[0032] Referring to FIGS. 4A and 4B alternative embodiments are shown with regard to the grid array pattern. FIG. 4A shows the bottom surface of a QFN package 10' having three different peripheral rows 18A, 18B and 18C of conductive elements 16. The conductive elements 16 are formed in a similar manner as described above except that additional severance regions 36 (or notches) would be located in each lead 16' and that there are additional concavities 30 to assist in forming the third peripheral rows 18C.

[0033] FIG. 4B shows the bottom surface of a QFN package 10" also having three peripheral rows 18A', 18B' and 18C'. However, in the embodiment of FIG. 4B the conductive elements 16" of the peripheral rows 18A', 18B' and 18C' are staggered such that a conductive element 16" in peripheral row 18B' is shifted slightly to one side as compared to an adjacent conductive element 16" in peripheral row 18A'. Similarly, a conductive element 16" in peripheral row 18C' is shifted slightly to one side as compared to an adjacent conductive element 16" in peripheral row 18B'. Such an arrangement is possible by forming a lead frame having leads 16' positioned at an angle other than perpendicular with respect to an adjacent edge of the die paddle 14. The individual peripheral rows 18A', 18B' and 18C' are formed in a manner similar to that described above, with elongated, trough-like concavities 30 being formed to ultimately create the individual conductive elements 16". The staggered configuration serves to allow more flexibility

in wire bonding configurations and potentially lower bond loop heights due to the lateral staggering of the conductive elements 16. Thus, depending on the angle at which a lead 16' is formed on a lead frame, the offset of one peripheral row relative to another may be controlled and wire bonding configurations may be flexibly designed.

[0034] Referring now to FIG. 5, an exemplary lead frame strip 50 including a plurality of individual lead frames 52 for use in forming QFN packages 10 is shown. The multiple lead frames 52 are formed in a single, longitudinally extending strip 50 as is known by those of ordinary skill in the art. Each lead frame 52 includes an outer frame portion 52o bearing a die paddle 14 supported substantially in the center thereof by tie bars and multiple inwardly extending, cantilevered leads 16'. A reduced number of leads 16' is shown for clarity, but is not intended to be limiting of the invention. The leads 16' are each formed with a severance region 36, such as a notch or similar recess, for subsequent formation of individual conductive elements 16 from the leads 16'. As discussed above, the severance regions 36 may be formed by various techniques such as scoring, saw cutting, or etching. The severance regions 36 define the locations of the peripheral rows 18A and 18B which will be subsequently formed in the QFN package 10. The lead frames 52 depicted in FIG. 5 are representative of a lead frame 52 which might be used in the formation of a QFN package 10 described in conjunction with FIGS. 1 and 2. Other lead frames of suitable configuration and with similar features would be utilized in forming the QFN packages 10', 10" discussed in conjunction with FIGS 4A or 4B respectively as is understood by those of ordinary skill in the art. In fabricating QFN packages of the present invention, the outer frame portions 52o are severed from the packages to effect electrical isolation of die paddle 14 as well as each set of conductive elements 16 from the outer frame portions 52o, while mutual electrical isolation between the conductive elements 16 formed from each lead 16' is effected by cutting through the leads 16' from the lead surfaces opposite the notches of severance regions 36. To facilitate alignment of the packages for creating the concavities or recesses 30, it is preferred currently that QFN packages 10 be severed from outer frame portions 52o after such concavities or recesses are cut or otherwise formed. If conductive bumps 28b are to be formed or placed on conductive elements 28, it may also be desirable to form or place conductive bumps 28b while

QFN packages 10 are still unsevered from lead frame strip 50 to facilitate alignment and handling.

**[To the inventors--Please confirm the foregoing statements as to the fabrication process]**

**[0035]** Referring now to drawing FIG. 6, a schematic of an electronic system 60, such as a personal computer, including an input device 62 (such as a keyboard and mouse) and an output device 64 (such as a display or printer interface) coupled or otherwise in electrical communication with a processor device 66, is illustrated. Processor device 66 is also coupled or otherwise in operable electrical communication such as through traces of a motherboard with one or more memory modules 68 incorporating a plurality of QFN packages according to the present invention such as 10, 10', 10" or variations thereof. The memory module 68 may include a memory board 70 having an electrical circuit formed therein, such as a PCB. Furthermore, processor device 66 may be directly embodied in a module with a QFN package which incorporates the teachings hereof and further include, without limitation, a microprocessor, a first level cache memory, and additional integrated circuits, such as logic circuits, a video processor, an audio processor, or a memory management processor.

**[0036]** While the invention may be susceptible to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and have been described in detail herein. However, it should be understood that the invention is not intended to be limited to the particular forms disclosed. Rather, the invention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the following appended claims.